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Releasing Fukushima Daiichi Nuclear Power Station Tritium to the Ocean – Getting the Issues Straight –

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1. Recent moves

Large amounts of radcontaminated water have been generated at the Fukushima Daiichi Nuclear Power Station (FDNPS) site by the mixing of fuel debris cooling water and groundwater flowing into the reactor and turbine buildings. This contaminated water is passed through radionuclides removal systems and stored in makeshift tanks as “treated water,” which contains the non-removable tritium [plus other residual radionuclides]. In the last seven years, the accumulated total of this “treated water” has surpassed the one million cubic meter mark[1] and the 1,000 m^3 tanks stand like a forest on the FDNPS site. As a result, it is reported that in just over three more years there will be no more land available for putting more tanks.[2] Thus the authorities involved have begun to scramble around to create a public-acceptance atmosphere for ocean release of this “treated water.”

At the same time, this problem is one that was known about at an early stage, with the government (Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry) establishing a Tritiated Water Task Force under the Committee on Countermeasures for Contaminated Water Treatment. The Task Force released “Tritiated Water Task Force Report” in June 2016.[3]

At the end of 2017, Chairman Fuketa of the Nuclear Regulation Authority, having said at a meeting for an exchange of views with Fukushima Prefecture municipalities that there was no scientific problem with the ocean release of the treated water, stated his view that TEPCO should make the decision on the discharge method within the year.[4] Furthermore, at the regular press conference on January 17, he indicated his concern that “the decommissioning of Fukushima Daiichi reactors would come to a standstill” if the decision on the release was to be further postponed.[5]

The result of a joint Asahi Shimbun and Fukushima Broadcasting Co., Ltd. public opinion poll conducted by telephone with respect to residents of Fukushima Prefecture on February 24 and 25 this year was that “when asked whether or not they agreed with the release of diluted treated water (accumulated in tanks on the FDNPS site) into the sea, those opposed outnumbered those in favor by 67% to 19%.”[6]

2. Who is responsible for the decision?

In the first place, it has not been clearly determined, in organizational terms, who is responsible for the decisions on work guidelines for the cleanup in the aftermath of the FDNPS accident. The composition of organizations for giving instructions and providing economic support to the TEPCO

Fukushima Daiichi Decontamination and Decommissioning Engineering Company consists of the Inter-Ministerial Council for Contaminated Water and Decommissioning Issues, the Nuclear Damage Compensation and Decommissioning Facilitation Corporation and the Nuclear Regulation Authority, but this is simply piling up one organization on top of another and very hard to understand.[7]

Quite predictably, it was reported that the TEPCO Chairman Takashi Kawamura and the former chairman of the Nuclear Regulation Authority, Shunichi Tanaka, engaged in a puerile and unprofessional argument in July of last year.[8] Both men made advertising-balloon-type statements, but appeared to have the intention of avoiding any responsibility for decisions. From the standpoint of taxpayers, we would like to demand that there is a clear indication of who is responsible. Without that, there is no way a forum for serious discussion can be created.

The person in the highest position of responsibility in the TEPCO Fukushima Daiichi Decontamination and Decommissioning Engineering Company, CDO Naohiro Masuda, in an interview with the Nihon Keizai Shimbun in March this year, stated, "It has become our common perception that tritium is not harmful. I would like to begin a dialog with local residents (on the disposal method)."[9] It was reported that "having stated that '(Ocean release) is one option,' Mr. Masuda reemphasized that 'I will take responsibility for realizing this in line with the government's decision.'" From the way the article was written, it appears that there is an awareness that it is the government who is responsible for making the policy decision. Just in the same way as the TEPCO Chairman Kawamura and the former chairman of the Nuclear Regulation Authority Mr. Tanaka engaged in their argument last summer, each insisting that the other should make the decision, CDO Masuda and Chairman Fuketa are recently engaging in similar arguments.

3. Various views on toxicity

(1) Factors impeding evaluation of the tritium risk

At issue with the tritium water ocean release is bioaccumulation in the ecosystem and the internal exposure of the general public when they consume materials from this ecosystem. However, for the following reasons, it is considered that there is almost no data available at present.

- In epidemiological studies, the subjects have very often ingested other nuclides at the same time, making it difficult to study the impacts of tritium alone.
- Experiments have been conducted on mice, etc. as an alternative means, but almost all of these studies have used high-dose exposures.[10]
- There is no data that clearly explains the degree of impact of tritium on living organisms.

(2) The view that considers there is no need to be concerned about the effect on the human body

The notion that there is no problem as long as the tritium is released after diluting to the regulatory standard concentration is as shown below.

Additionally, the concentration level at which it is necessary to report an ocean release is 60,000 Bq/L, and naturally the government and power plant operator premise the diluted release on this condition.

a. Ministry of Health, Labour and Welfare[11]

- It is considered that since tritium exists as water in seawater, even if it is ingested by humans or fish and shellfish, etc. it will be rapidly excreted and does not (bio)accumulate.
- Impacts of tritium on living organisms are very small, being about one-thousandth of that of radioactive cesium, which is used as the standard for radioactive substances in food.
- As far as can be seen from the results of measurements of the seawater carried out thus far in the waters around TEPCO's FDNPS, there is no cause for concern about the effects of tritium on marine products distributed to the market.

b. Shunichi Hisamatsu (Head of the Department of Radioecology, Institute for Environmental Sciences, Rokkasho, Aomori)[12]

There are no reports thus far of serious health effects (from the release of tritium into the sea) from any country.

c. Japan Nuclear Fuel Limited[13]

Supposing 18,000 terabecquerels are released into the ocean each year, local fishermen go out fishing every day and eating the marine products, and even if one keeps staying for the whole year around the release outlet, the annual exposure dose would be 0.022 mSv, which is lower than the annual 1 mSv dose from the natural environment in Japan.

(3) Opinions expressing concern about the effects on the human body

a. Chihiro Kamisawa[14]

There are concerns about internal exposure from internal ingestion. When tritium is taken into the human body as tritium water, a part of that is incorporated into cell nuclei, and there is a possibility that it will replace hydrogen atoms that make up DNA (genes). In this case, the low energy level and the short distance of penetration of the beta radiation released by tritium is extremely effective at damaging genes and there is research that indicates that the dangers of this should be seen as greater than gamma radiation. It is thought that this becomes more serious when the tritium behaves as organic tritium. When tritium is part of an organic compound, it is considered to be more easily absorbed into the human body, more easily incorporated into cell nuclei where it may remain for long periods of time.

b. Toshiyuki Umata (Radioisotope Research Center, University of Occupational and Environmental Health)[15]

The modality of tritium exposure is thought to be low dose and low dose rate internal exposure, but tritium water taken into the body orally, by inhalation, or by absorption through the skin is thought to have impacts that are not insignificant due to an even distribution throughout the body. Moreover, tritium taken into organic bonds accumulates in the form of the body's biomolecules, and as these result in long-term exposure it is important to take the chemical form of the tritium in the body into account.

c. Junichi Kowaka (Editor of *Food and Safety in Daily Life*)[16]
When tritium is taken into cells, and, furthermore, enters the nucleus, as it approaches closer to the DNA, in the same way as radioactive cesium and strontium, it attacks the DNA. (Tritium emits radiation to become helium; the part of the DNA which has changed to helium is then broken and the gene with then "malfunction." Since this malfunction adds to other existing risks, the rate of occurrence of cancer becomes higher with tritium.

(4) Tritium ingestion standard[17]

Japan has no standards for tritium in drinking water. However it has been pointed out that as a result of a lack of regulation, 60,000 Bq/L is the default standard for drinking water.[18] There is a wide range of standards issued by regulatory agencies around the world, with WHO at 10,000 Bq/L, Canada at 7,000 Bq/L (Ontario Drinking Water Advisory Council recommends 20 Bq/L)[19], USA at 740 Bq/L and the EU at 100 Bq/L.

4. Cases of the handling of tritium in Japan and overseas[20]

As shown in the previous section, there is no accepted theory – each country has taken a prudent stance toward tritium, as shown below.

(1) The case of the Three Mile Island nuclear accident
In the Three Mile Island accident, roughly 2.43×10^{13} Bq of tritium (approximately 8,700 m^3) was disposed of by steam release to the atmosphere.

(2) The case of France
The annual releases of tritium from the La Hague reprocessing plant are roughly 1.2×10^{16} Bq of liquid and roughly 7.0×10^{13} Bq of gas. As the necessity for an evaluation of organic tritium within France was pointed out, the Nuclear Safety Authority (ASN) produced a report known as the "Tritium White Paper" in 2010. Subsequently, the nuclear facilities operators have prepared and published regular reports.

(3) The case of the UK
The EU fusion experimental reactor JET at the Culham Centre for Fusion Energy (CCFE) burns deuterium and tritium. It has a system which recovers tritium from cooling water, etc. that contains a high concentration of tritium, using methods such as electrolysis, cryogenic separation, etc.

5. Options for the handling of tritium water and their evaluation

(1) Tritiated Water Task Force Report

Broadly divided, the Task Force Report mentioned above gives the following five kinds of disposal methods along with their concept designs and approximate cost estimates. The most severe conditions are an original concentration of 4.2 million Bq/L, a treatment speed of 400 m^3/day and an original amount of 800,000 m^3 (to compare the evaluations below for the case of one million m^3 of tritium water, the evaluations are increased by roughly 25%).

- Injection into geological strata: (in the case of injection following dilution)
  For just the injection cost, if surveys for injection wells were to be carried out for about 20 locations, this would require around 620 billion yen, but the long-term monitoring cost is unknown (new R&D would be necessary)
- Ocean release: (in the case of ocean release following dilution)
  Around 3.4 billion yen
- Steam release: (steam release without pre-treatment)
  Around 34.9 billion yen
- Hydrogen release: (hydrogen release without pre-treatment)
  Around 100 billion yen
- Subsurface burial: (deep subsurface burial without pre-treatment)
  Around 253.3 billion yen

(2) Report of the Japan Center for Economic Research

The Japan Center for Economic Research has released a report entitled “The Fear that the Accident Cleanup will Cost 50 to 70 Trillion Yen”.[21]

The report presents two trial calculations for the cost of the disposal of tritium water.

- Disposal of the stored tritium water at a unit cost of 20 million yen/m^3 would amount to 20 trillion yen. The report does not give details of any process specifications.
- In the case that all the tritium water is disposed of by ocean release, the cost is not given as it is small. However, 300 billion yen is allocated for compensation for ‘harmful rumors’ (consume caution regarding consumption of marine products from the area) over a period of 40 years. The calculation is based on giving compensation of ten million yen per year to each of 1500 people related to the Fukushima fishermen’s association in the first year, which is reduced each year until it reaches zero in 40 years’ time.

(3) Citizens’ Commission on Nuclear Energy Report

The authors, the Citizens’ Commission on Nuclear Energy (CCNE) have issued a Special Report 1 entitled “Settlement After 100+ years of Shielded Isolation” (revised edition, 2017).[22]

The report proposes that since at present there are various theories about the hazardous effects of tritium, ocean release not be forcibly implemented but the tritium be stored permanently in tanks until the dangers of tritium have been fully examined.

Specifically, ten 100,000-ton large-scale tanks, of the kind currently being used in the national oil reserve base, should be constructed and the tritium water stored for 123 years, when it is expected that the radiation will have decayed to one-thousandth of its current value. Thus it is proposed that the tritium be managed in this way in order to wait till the radiation has sufficiently decayed. To implement an inspection by opening the tanks and removing the tritium water about once every 20 years, if one extra tank is constructed, at a unit cost of three billion yen per tank, 11 tanks would cost 33 billion yen, which is very similar to the 34.5 billion yen paid for the frozen barrier around the FDNPS buildings. Moreover, the design specifications could apply tried and tested methods already used in the national oil reserve base, such as constructing a retention dike around the facility to provide against accidents. If a further degree of decay is required, more storage tanks of a similar specification can be constructed to replace those whose lifetime has expired, following which the tritium water is stored in the tanks for a further 123 years, during which time the radiation can be expected to have decayed a further order of one-thousandth.

Let us consider around how much, when compared with amounts of tritium released when FDNPS was operating normally, is represented by the current amount of stored tritium if it is managed for 123 years.

a. Accumulated volume of tritium in tanks

   As of March 24, 2016, the accumulated amount of tritium in the water stored in the tanks was roughly 7.6E+14 Bq.[23] If this is reduced to one-thousandth, the amount is around 7.6E+11 Bq.

b. Annual amount released to the ocean before the accident[24]

   Prior to the accident, during fiscal years (FY) 2002 to 2009, the actual annual amount released to the ocean from FDNPS reactor units 1 to 6 (all the units at the site) was 7.8E+11 to 2.6E+12 Bq, or an annual average of 1.5E+12 Bq.

From this result, it can be expected that the amount of tritium would be less than the minimum actual annual amount that was released to the ocean in the period FY2002 to FY2009.

Regarding safety measures against earthquakes, the construction of a retention dike would be realistic, using existing tried and trusted methods to prevent any possible leaks. It is thought that it would be possible to utilize the proposed construction site for FDNPS reactor units 7 and 8 to construct this large-scale tank facility. In addition, since these large-scale tanks use space much more efficiently, their volume stored per unit area of land required is much higher than the 1,000-ton tanks currently being used on the FDNPS site and it is thought that if the construction of the new tanks were implemented in parallel with the removal of the current tanks, the new tanks could be constructed on the area covered by the existing tanks.

Furthermore, what currently known as “tritium water” has been passed through water treatment radioactive substance removal apparatuses to remove the radioactivity due to other nuclides, but the authors have no information as to whether or not these have been 100% completely removed or not. If there are uncertain factors regarding this point, there would surely be no loss from waiting for the radioactivity of these other nuclides to decay.

6. Conclusion

The toxicity of radioactive substances is not yet fully understood. That is also true of harm from tritium. Rather than disperse toxic materials into the environment, the fundamental lesson learned from many years of the country's serious industrial pollution is that toxic materials should be centrally managed and released into the environment only after they have lost their toxicity. The CCNE proposal outlined in (3) above is technologically and economically viable, using well-proven engineering at the current industrial level, and is the most stable and safe solution of all those proposed.

As stated at the outset, in the present situation, where an opinion poll has shown that 67% of Fukushima residents are opposed to ocean release, it is morally reprehensible that a unilateral decision to discharge radioactive water into the ocean be taken by those who are responsible and liable for the nuclear accident, the government and TEPCO.

Endnotes: (All in Japanese except when indicated with an asterisk *)

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3. Tritiated Water Task Force Report, June 2016:
   http://www.meti.go.jp/earthquake/nuclear/osensuitaisaku/committtee/tritium_tusk/pdf/160603_01.pdf (Japanese)
   http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20160915_01a.pdf (English)
   With explanations: "Regarding the Tritiated Water Task Force Report," November 11, 2016, and others:
   http://www.meti.go.jp/earthquake/nuclear/osensuitaisaku/committtee/takakusyu/pdf/001_03_00.pdf
4. "TEPCO urged to discharge or dispose of treated water," Denki Shimbun, January 16, 2018
5. "Judgment required for release of Fukushima Daiichi treated water," Denki Shimbun, January 18, 2018
6. "66%'feel anxious'about radioactive substances - Fukushima Prefecture poll," Asahi Shimbun, March 3, 2018
7. "Our Path to a Nuclear-Free Japan 2017", p.97 http://www.ccnejapan.com/?page_id=8000
   Tetsuro Tsutsui, "Delay in 'the government coming the forefront': Disorderly establishment of organizations obstructs contaminated water treatment," *Kagaku*, Vol.83 No.11 (2013) p.1203
8. "TEPCO Chairman, 'We are making a judgment on the ocean release of the treated water'," Nihon Keizai Shimbun, July 19, 2017
   "Repercussions from the TEPCO chairman's statement – backlash from fishermen and regulatory commission on release of treated water," Nihon Keizai Shimbun, July 21, 2017
9. "Treated water release: 'Dialog with local residents'," Nihon Keizai Shimbun, March 5, 2018

10. Toshiyuki Umada, Megumi Sasatani, Akira Tachibana, “Evaluation of Impacts of Tritium on Living Organisms,” *Journal of Plasma and Fusion Research*, Vol.88, No.3 March 2012

11. “Frequently asked questions,” Ministry of Health, Labour and Welfare website

12. “Removing radioactive substances from contaminated water,” Sankei Shimbun, September 23, 2013

13. “Tritium removal difficult,” Nihon Keizai Shimbun, September 8, 2013

14. Chihiro Kamisawa, “The Tritium Contaminated Water at Fukushima Daiichi Nuclear Power Station,” *Kagaku*, Vol.83, No.5 (2013) p.505

15. “Evaluation of Impacts of Tritium on Living Organisms,” *Magazine of the University of Occupational and Environmental Health*, Vol.31, No.1 (2017) p.25

16. “Don’t release tritium (tritiated hydrogen) contaminated water – steam is also frightening!” *Food and Safety in Daily Life*, No.275, March 1 (2012) p.5

17. *Canadian Nuclear Safety Commission, “Tritium in Drinking Water,” August 20, 2009 http://nuclearsafety.gc.ca/eng/resources/health/tritium/tritium-in-drinking-water.cfm

18. Masako Sawai, “Current State of Fukushima Daiichi Nuclear Power Station,” *Medical Treatment for Workers and Residents*, February 2018, p.11

19. *“Report and Advice on the Ontario Drinking Water Quality Standard for Tritium,” May 21, 2009

20. Tritiated Water Task Force Report, p.6 (See Endnote 3)

21. “Future of Energy and Environmental Choices (Extra Editoin) – Public Financial Burden of the Fukushima Nuclear Accident,” March 7, 2017

22. Published on November 11, 2017, p.7 http://www.ccnejapan.com/?p=7900

23. Tritiated Water Task Force Report, p.5 (See Endnote 3)

24. Japan Nuclear Energy Safety Organization, “Yearbook of Nuclear Energy Facility Operation and Management,” 2012 Edition, p.608 http://www.inaco.co.jp/isaac/shiryo/pdf/genpatu/jnes_24.pdf